REVISTING WAIKOUAITI, WHY LEAD IS STILL IMPORTANT.

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ABSTRACT (500 WORDS MAXIMUM)

On the 2nd of February 2021, a "Do Not Drink" notice (DNDN) was put in place for the communities of Waikouaiti, Karitane and Hawksbury Village due to elevated lead readings in the drinking-water supply. That notice was to remain until 28th of July, during which time a comprehensive screening of blood lead levels in the communities was undertaken. This paper provides a brief summary of the events in Waikouaiti and discusses the limitations of Maximum Acceptable Values (MAV) when faced with potential short term, intermittent chemical exposures. The emerging science around lead toxicity is also outlined to highlight why managing lead exposure continues to be important.

As part of a water sampling programme, outside of routine compliance sampling, the Dunedin City Council (DCC) detected elevated lead levels in drinking-water from the Waikouaiti Golf Course. The first elevated result was returned in July 2020. Samples continued to be taken over the next six months and a further 6 samples from various supply-side sites showed evidence of elevated lead. Then in January 0.05 g/m3 (mg/L) total lead was detected in the raw water reservoir exceeding the MAV for drinking water of 0.01 mg/L. Immediately a DNDN was put in place and a community blood lead level screening programme was initiated. All residents were invited to participate and within a four-week period over 1500 people had taken part. Interestingly, very few blood levels were detected above the threshold limit and there was no apparent difference between those who drank from the Waikouaiti supply and those who didn't. Following an extensive investigation, the DCC found that there is no widespread lead in the drinking water network.

Lead accumulates in the body over time and experts have suggested there may be no safe level of exposure. The MAV for lead in New Zealand aligns with the World Health Organization recommendations. The neurological (brain) effects of lead are the most concerning with exposure in children linked to decreased IQ, behavioural effects, and delayed puberty. In recognition of this in 2021 the New Zealand notifiable blood lead level was decreased from 0.48 µg/L to 0.24 µg/L.

Due to the fact that lead accumulates in the body, determining the risks from multiple short-term exposures is difficult. Most analyses classify acute lead

exposure as being constant for three months or more. To model the potential harm from the potential intermittent Waikouaiti exposure, the EPA All Ages Lead Model (AALM) was used. This tool predicted elevations in blood lead levels if the exposure pattern repeated for two years or more. Additionally, new experimental studies suggest that exposure to lead can not only affect the exposed individual but also future generations (children and possibly grandchildren). While these studies are laboratory based, the combined evidence shows that intermittent lead exposure is a potential risk and must be managed appropriately.

KEYWORDS

Lead, Drinking Water, Public Health, Chemical Contamination, Drinking Water Standards, Maximum Acceptable Value (MAV), Waikouaiti

PRESENTER PROFILE

Belinda Cridge is a toxicologist working within ESR. Her main role is to provide scientific advice to support the aims of providing safe drinking-water to everyone in New Zealand.

John McAndrew is a Chartered Chemical Engineer with over 18 years' experience. He started his career in the UK and spent eight years in Sydney before joining the team at Dunedin City Council where he is the Plant Operations Manager.

Rosemarie Nelson joined Tasman District Council in April 2022 after 23 years as a Health Protection Officer and Drinking Water Assessor for Public Health South.

INTRODUCTION

Lead is a cumulative neurotoxin that has no known functional role in the body. Therefore, efforts are underway worldwide to reduce exposure to this heavy metal with focused campaigns run through organisations such as the World Health Organization and the implementation of a variety of regulatory standards. Historically, the primary mode of lead exposure was leaded petrol but after this was banned in 1996 [1] other sources such as paint and, increasingly, drinking-water have become important exposure routes [2].

Lead in drinking water is more commonly associated with international situations. From 2014 to 2017 the residents of Genesee County and the city of Flint in Michigan were exposed to high levels of lead in their drinking-water after the source water was changed. The high corrosivity of the new water source was not adjusted and lead began to leach from service lines (the pipe connecting the water main to a building) [3]. In the US, the connection between the water main and the household supply line commonly uses a fitting called a gooseneck, often made from lead as it is resistant to degradation at a range of temperatures [4]. Lead is also added to a range of plumbing fittings as it is malleable which makes manufacture easier. However, when lead is near other metals or exposed to a high or low pH liquids then it will corrode. In Flint, Michigan the change in water led to corrosion and over 200 cases of children with elevated blood lead levels. Similar factors in drinking-water in Washington D.C. caused over 42,000 children to be exposed to lead and a possible 200 fetal deaths [3].

From drinking-water lead is taken up by the body and accumulates in the bones and teeth. Children and infants absorb up to 50% of ingested lead while adults will absorb only 10-15% [5]. The half-life (time it takes to remove half of the lead present) of lead in the blood is around 30 days but in bones the half-life is 20-30 years. As children are growing and developing, the rate of deposition of lead into the bones is considered greater. The combined effect of greater uptake and greater storage means that even in elderly patients (70 years plus), more than a third of lead present in their system can be estimated as coming from childhood and adolescent exposures. The lead from childhood then acts as a reservoir, releasing lead into the blood stream continually over a lifetime.

Children are particularly sensitive to the toxic effects of lead. Lead causes a range of neurological effects including impacts on IQ, behavioural effects such as impulsivity and hyperactivity, and delayed puberty. Lead also affects the kidneys and blood and, in adults, causes increased blood pressure and hypertension, particularly in pregnant women [2]. Lead from a pregnant mother can also be transferred to the foetus and will start to contribute to the child’s lead burden before it is even born.

Therefore, for health reasons lead is regulated as part of the New Zealand Drinking-Water Standards [6]. The current Maximum Acceptable Value (MAV) for lead is 0.01 mg/L in a flushed sample. As household plumbing, such as tapware, contain lead a 500ml flush is normally performed prior to compliance sampling. This initial flush will often contain high levels of lead and other metals, particularly if the tap hasn’t been used for several hours [7], which is why it is recommended (in DWSNZ) to flush taps in each day. Elevations above 50% of the MAV are required to be investigated. Historically in New Zealand there have been very few lead compliancy issues that have resulted in a coordinated public health response, until lead was detected in the raw (untreated) water reservoir of the water supply in Waikouaiti, Dunedin, resulting in a Do Not Drink notice being issued in February 2021.

INTIAL DETECTION TIMELINE

Sampling outside the normal DWSNZ compliance programme was initiated in July 2020 to inform a corrosion control strategy for the Waikouaiti Water Treatment Plant as part of the planned upgrade to this facility. Lead was not regularly measured prior to this sampling program.

The water from the Waikouaiti Treatment Plant supplies the communities of Waikouaiti, Karitane and Hawksbury, with a combined population of approximately 2,000 people. Water is sourced from the Waikouaiti River and stored in a raw water reservoir. Raw water is membrane-filtered and treated with chlorine and soda ash prior to storage in a treated water reservoir (located at the WTP). The distribution system includes four distinct distribution zones – Waikouaiti Upper, Waikouaiti Lower, Karitane and Apes Road (see Figure 1). Hawksbury village is supplied by a private distribution network via a metered connection.

The first detection of lead was on the 31st of July 2021 when a sample from a private tap at Waikouaiti Golf Club showed 0.0295 mg/L lead present. These results were notified to Public Health South on the 14th of August 2020. Further elevated

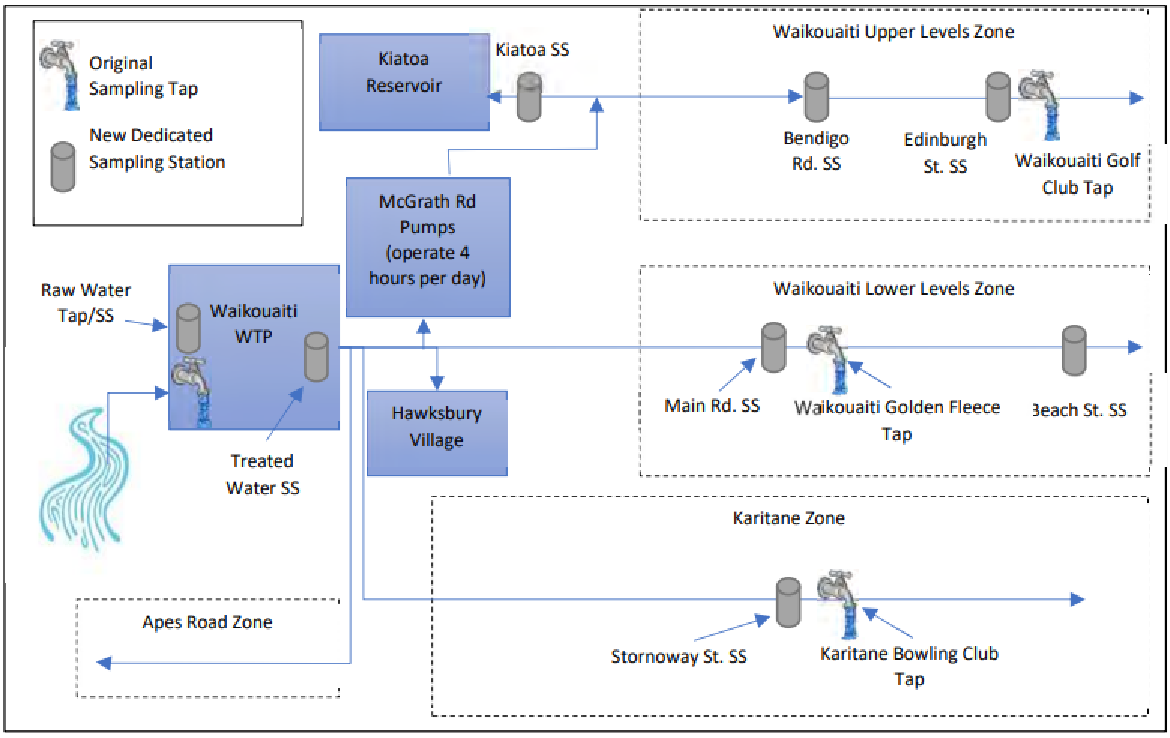

Figure 1: Waikouaiti, Karitane, and Hawksbury Village Water Supply Scheme

readings were recorded on the 9th of October in Waikouaiti distribution (0.012 mg/L), the 30th of October at Karitane Bowls club (0.017 mg/L pre-flush), the 8th of December at both the Karitane Bowls Club (0.0.072 mg/L) and Waikouaiti Golf Club (0.394 mg/L) and on the 31st of December at the Waikouaiti Bowls Club (0.0266 mg/L pre-flush). The results from the 8th of December were of particular concern as they occurred in different locations on the same day and exceeded the MAV by approximately 40x at the Waikouaiti Golf Club.

In January of the following year (2021) the seventh exceedance was noted, a reading of 0.0178 mg/L, again at the Waikouaiti Golf Club. After consultation with the drinking water assessor (Wai Comply Ltd), Public Health South was notified of the elevated readings and public health support sought for the ongoing investigation. Shortly after this on the 20th of January 2021 a reading of 0.05 mg/L lead was recorded in the raw water reservoir (prior to treatment). The history of elevated readings with the elevated result from the reservoir led the Medical Officers of Health to recommend on the 2nd of February that a Do Not Drink Notice should be issued for the Waikouaiti supply. At this stage investigation processes were initiated, a health response and a supplier response.

SUPPLIER RESPONSE

Following the announcement of the DNDN, a dedicated response plan was developed which established a multi-agency Response Management Team and included Investigation, Operations, Public Information and Community Engagement workstreams. The investigation was documented in a report which was shared publicly and this section includes a brief overview [8].

The investigation team began gathering data, assisting the event response, working to understand the causes of the elevated lead results and assisting with characterising the risks to public health, if any. A key aspect of this investigation was to understand the cause of the exceptional values on the 8th of December 2020 and the 20th of January 2021. These results were considered 'exceptional' because they were not typical of readings from the respective sample locations.

An enhanced sampling programme was initiated that included increased quality assurance measures (e.g. duplicate samples), increased sampling frequency (daily at most sites), installation of an autosampler to monitor the river intake, installation of a continuous lead monitor, use of handheld lead analysers sourced from the USA, and a data sharing process across the Dunedin City Council, Public Health South and the Drinking Water Assessor (Wai Comply). Additional locations were included in the sampling plan (e.g. the Golden Fleece Hotel in central Waikouaiti, raw water, treatment plant and reservoirs) and new dedicated stainless steel sampling taps were fitted at selected sites across the distribution system. Both pre-flush and post-flush samples were collected.

Once the dedicated stainless steel sample taps were installed, results showed some fluctuating lead levels in pre-flush samples, but post flush samples were significantly lower compared to results from customer taps in the same locality e.g. Waikouaiti Golf Club (Figure 4). The new stainless steel sampling tap on Bendigo Road also showed elevations in pre-flush samples with post flush samples being significantly reduced (Figure 6). A similar tap on Beach St/Stewart St showed consistently low lead levels (Figure 5) in both pre and post flush samples. Plastic sample taps were installed adjacent to the 210 Edinburgh St and Bendigo Rd taps and volumetric profile samples were also taken – these confirmed the source of pre-flush lead readings in stainless steel taps was leaching from the tap itself (which had typically been stagnated for approx. 24 hours).

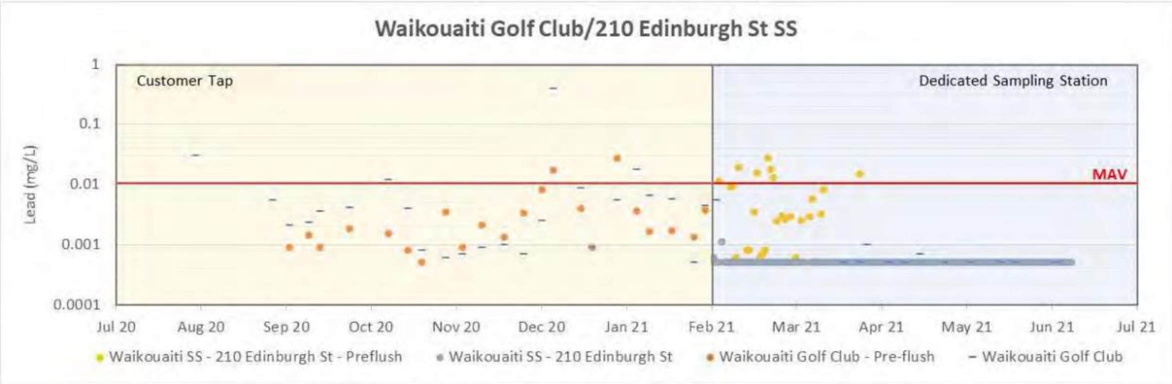

Figure 4: Lead Measurements at Waikouaiti Golf Club and 210 Edinburgh St SS (31/7/20 – 14/6/21)

Note: The continuous grey line from early February 2021 to June 2021 is due to high frequency (daily) samples which were all at the same level (i.e. less than LOD)

Figure 5: Lead Measurements at the Intersection of Beach St and Stewart St SS (23/2/21 – 8/6/21)

Figure 6: Lead Measurements at Bendigo Rd SS (1/3/21 – 15/6/21)

Note: The continuous blue line from early February 2021 to late May June 2021 is due to high frequency (daily) samples which were all at the same level (i.e. less than LOD)

In addition to water sampling, multiple possible causes of the contamination were investigated including potential analytical errors, lead leaching in the distribution network, lead leaching in local plumbing, raw water contamination, plant operational issues and backflow. Some of the actions taken were:

- Sampling protocols were reviewed and some changes were made but overall the sampling and analysis could not account for the lead detections.
- Lead leaching from the distribution was a possible cause as some pipes dated from 1913 and were due for replacement. However, detailed assessments carried out by WSP showed that the lead components were not in contact with the water supply and would be unlikely to have contributed to the observed results.
- Stagnation tests were performed on brass manifolds from the Waikouaiti Golf Club and the Karitane Bowling Club. The results showed that relatively high levels of lead (>10 times the MAV) could originate from these fixtures, samples from the Karitane Bowling Club manifold were observed to contain particulates which could have contributed to the high lead reading on the 8th of December. However, without details of the exact stagnation times and water chemistry on this particular day it is impossible to say this was indeed the direct cause.
- Profile sampling of the customer taps at the Waikouaiti Golf Club and Karitane Bowls Club also showed the potential for these to act as sources for lead. Long service lines, particularly to the Waikouaiti Golf Club, meant that the standard flush times were insufficient for samples to be representative of the distribution system with a flushing time of over 10 minutes needed.
- A catchment risk assessment carried out by Tonkin & Taylor showed a range of potential contamination sources but found no evidence of elevated lead results in the river or sediment. The report concluded that sustained elevated discharges of lead within the river catchment were unlikely and there was no evidence to indicate that point sources were present, that were sufficient to cause the downstream lead elevations.
- There were four breakages in the network prior to the 8th of December 2020 but backflow analysis concluded that it was very unlikely that one of these contributed to the elevated lead on that day. Further investigation showed that all backflow prevention devices were functioning at the times of the lead detections.

Overall, the investigation took almost six months and involved intensive work across multiple teams. The findings suggest that the most likely cause of the elevated readings at the Waikouaiti Golf Club and Karitane Bowls Club was lead leaching from pipes and fittings at the point of supply, not the drinking-water network. The elevated reading from the raw water reservoir on the 20th of January 2021 was most likely to be due to lead in the sediment from the raw water or particulate material from the sample tap. This particulate matter would be expected to be removed by the water treatment process.

HEALTH RESPONSE

Ongoing exposure to lead over an extended period poses a significant health risk, particularly to children. In this instance the water monitoring results had shown intermittent increases in lead exposure in the six months prior to the involvement of the Public Health Team. The first decision taken by the health team is that a Do Not Drink Notice (DNDN) should be implemented and this was issued by the Dunedin City Council on the 2nd of February 2021.

Due to this unusual pattern of potential exposure, a definitive public health risk assessment could not be ascertained from the sampling data alone. On the 4th of February the decision was made that screening of blood lead levels in the community would assist in determining whether there had been ongoing exposure to lead for an extended period. A community meeting was held on the 5th of February which was attended by both Public Health South and Dunedin City Council representatives. The issues with the water were discussed and the proposal for free blood lead level testing put forward.

Sampling commenced on the 9th of February 2021. The majority of sampling was undertaken within the local community but was made available to residents who may be temporarily located elsewhere across the country. In total, 1512 people were tested. As part of the screening process a questionnaire was completed to inform the health teams of other potential sources of lead exposure (e.g. paint and recreational activities such as hunting). A total of 1159 participants were included in the final analysis. Most were over 65 years of age but the data largely matched the census reports for the area, except for a noticeable lack of representation in the 18-19 year old group.

At the time of the study, the notifiable blood lead level was 0.24 µg/dL and most people were below this threshold value. As expected, blood lead levels were generally higher in the older age groups and the data was similar to patterns observed overseas. This was the first recent survey in New Zealand that included children under 5 years old but for the 5-9 year old age group the blood lead levels were slightly higher than the previous national survey. For children 10-17 years old, the blood lead levels were similar to the previous national survey. For children who did have higher levels, factors such as living in an older house (pre-1945) or living in a house with peeling paint/renovations were important. For the adults that had an elevated blood lead level, factors such as eating shellfish, drinking roof water, living with renovations, a high-risk job, working with cars and ship/boat building were important.

Across the study, there was no evidence of a difference for those who drank from the local supply with those who didn't. This confirms that the public health risk from this event was minimal and that the drinking-water was unlikely to have caused continuous, ongoing exposure to lead.

After the health response had concluded, an academic exercise was undertaken to review the most current research on lead toxicity and also trial computer modelling of lead blood levels following intermittent exposure patterns.

It is well known that lead can be transferred from the mother's body to a developing foetus. What is now starting to emerge from the animal experimental literature is that the effects of maternal exposure may persist for multiple generations. Currently the evidence comes predominantly from rodent studies, where the lead exposures across multiple generations can be closely controlled. These studies show that lead exposure results in changes in epigenetic markers [9-11]. Epigenetics is a rapidly developing field and involves studying the signalling molecules that surround the DNA in a cell and control how the DNA is used. Unlike genetic changes, which are changes to the DNA itself, epigenetic changes are not directly linked to cancer. Instead, changes in these signalling molecules can result in a range of long-term health effects and have been linked to negative health outcomes such as obesity, fertility, Parkinson's disease, cardiovascular disease and more. Like genetic (DNA) effects, damage to epigenetic markers can be inherited from one generation to the next. Therefore, many researchers now believe that the damaging effects of lead can influence not just the person exposed, but also their children and possibly grandchildren [12-14]. For children and grandchildren of an exposed mother, the effects potentially include low-birth weights, increased risk of preterm birth, growth restriction, birth defects and cognitive impairment [9]. The effects of lead may also last into adulthood where they may manifest as pre-dispositions to a range of conditions such as obesity, coronary heart disease, cancer and neurodegenerative disorders [9].

Given the emerging evidence of long-term effects of lead exposure a computer modelling exercise was performed to see the potential changes in blood lead levels if action had not been undertaken. There are two main models used to predict potential blood levels following an exposure. Both have been developed by the US EPA but have different parameters. The Integrated Exposure Uptake Biokinetic (IEUBK) model is the most widely used and allows a range of potential exposure pathways to be included into a final prediction of blood lead levels. However, it presumes that the receptor (person being exposed) has constant exposure to the various sources of lead over a period of at least three months and is not always applicable to children [15, 16]. This does not apply to the current scenario whereby the sampling showed peaks of exposure on independent days. For this the All Ages Lead Model (AALM) is a more appropriate simulation platform [17]. Therefore, the AALM was used to model the exposures pattern from Waikouaiti but over 1-, 5- or 10-year periods. The highest reading of 400 µg/L of lead occurring in a pulsed pattern every two months was used for the possible exposure. All other lead sources were maintained at background levels (i.e., no occupational exposure or renovations occurring). Fortunately, this modelling showed only minimal predicted impact of infrequent but recurrent spikes in lead levels. While blood lead levels did increase during the exposure time, in all scenarios the blood lead level decreased once exposure ceased. However, in a scenario where the lead exposure was not addressed, no recovery was observed.

Additionally, only blood lead levels were modelled. Therefore, no predictions on bone retention can be made.

CONCLUSIONS

Overall, the occurrence of lead in the drinking-water samples in the Waikouaiti area are likely to have been caused by corrosion of lead-containing plumbing. While some manifolds may have been involved, the major issue, like elsewhere in New Zealand, was most likely customer fittings. Fortunately, the health investigation showed that the population of this area had not been unduly affected by the corrosion issues. However, the ongoing science investigation highlights the risks of customers not being proactive about managing lead exposure and suggests that underlying health effects may continue for many generations.

A Review of the Health Response into Waikouaiti water supply lead contamination was undertaken in March 2021. The report contains twelve recommendations relevant to incidents of this nature:

1) Laboratories must report exceedances in drinking-water to the Director-General of Health.
2) A reminder be sent to all registered drinking-water suppliers reminding them of their duties regarding exceedances of chemical contaminants, ask them to review internal communications, and agree planned monitoring projects with their Drinking Water Assessor (DWA).
3) Taumata Arowai charged with providing clear instructions, procedures and notification forms for incident and event notifications.
4) The Director-General of Health to send out communications on reporting exceedances outside the Priority 2 determinand system.
5) Taumata Arowai asked to consider mechanisms for supporting a risk management approach to drinking-water management rather than prescriptive requirements.
6) The Director-General of Health to remind drinking-water suppliers to assess the risk of lead leaching from their infrastructure as part of the risk assessment process.
7) Expedited processes for access to expert advice for Public Health Units was recommended.
8) The relationship between Taumata Arowai and the Public Health System should be made clear.
9) That database systems allow for timely access to information which can be readily shared.
10) Taumata Arowai to consider ongoing disclosure and transparency of monitoring results.
11) The Ministry of Health, Taumata Arowai and other relevant parties undertake a review of the current plumbing standards around allowable lead levels.
12) The Ministry of Health reviews the requirements for managing plumbosolvency and ensure notifications to consumers includes information on reducing exposure to lead.

With the changing legislative framework and the establishment of Taumata Arowai as the regulator, many of these recommendations have been either met or rendered obsolete. In 2022, MBIE included a reduction in allowable lead within plumbing fixtures as a part of the Building Code Update proposals. Final decisions on this are due in late 2022 with changes coming into effect in 2025. However, little continues to be done on educating consumers on plumbosolvency and the issues of lead. Under the new regulatory system, this will require a joint effort across drinking-water suppliers, Taumata Arowai and the Ministry of Health.

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